Appendix D: Direct Connection to Clifton Court Forebay

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D.1 Introduction

A direct connection to Clifton Court Forebay (CCF) from the Bacon Island Santa Fe Cut Integrated Facility is being considered to supply make-up Environmental Water Account (EWA) water for EWA imposed SWP/CVP export curtailments. This direct connection would be in addition to the proposed configuration and operation of the Bacon Island Santa Fe Cut Integrated Facility. Pumping units along with a conveyance system and an outlet channel would be added to the proposed facility to convey 900 cfs directly to CCF. This direct connection cannot be justified due to costs outweighing the benefits, but it may be considered as a part of the proposed fish screens at the new CCF intake, reducing the required screen size of the new CCF intake. With that said, the cost of this direct connection will not be added to the overall In-Delta Storage Project cost. Instead, the cost of this direct connection could be counted as an avoided cost of the proposed fish screens at the new CCF intake project, if deemed justifiable.

D.2 Design Criteria

The approximate length of the conveyance system from Bacon Island to CCF is about 30,000 feet and the design capacity of the system is 900 cfs. Water level variations at each integrated facility site are given in Chapter 2, Table 2.2 of this report. The water level in CCF varies from 2 feet below mean sea level to 5 feet above mean sea level. The design criteria used in this analysis are listed below.

1. The velocity in the pipeline shall not be less than 8 ft/sec and not more than 12 ft/sec.
2. Pipe material and foundation type shall accommodate the potential for settlement.
3. Depth of cover shall be a minimum of 6 feet.
4. Air valves shall be placed at high points to release trapped air.
5. Access manholes shall be placed every 500 feet.

D.3 Conveyance Alternatives

A qualitative evaluation of conveyance alternatives was carried out prior to designing the proposed alternative. Both gravity and pressure flow systems were considered to convey water from Bacon Island to CCF. A gravity system would consist of either open channel flow or pipelines and a pressure system would consist of either a buried or above ground pipeline.

D.3.1 Open Channel

An open channel gravity flow conveyance system was considered and could consist of either a lined or unlined canal. In an unlined canal the channel velocity must be limited to maintain embankment stability. Also, the side embankments should be nearly impervious to minimize losses and other problems due to seepage, otherwise seepage extraction wells would have to be installed. A lined canal would be more desirable given these conditions.

Due to its location and the nature of Delta soils, the canal's underlying peat soil may need amendments (removed and replaced or other) to improve the foundation conditions and overall stability of the canal. Sufficient freeboard should be provided to prevent overtopping of the canal during design flows and wave run-ups. Due to the lack of grade change in the existing ground profile, the upstream end of the canal would need to be raised in order to provide enough head to convey the design flow. This would likely require pumping to lift the water to the beginning of the canal. Bridges and culverts would be needed at existing road and canal crossings. A large footprint would be required to construct the canal and side embankments, which could impact existing farming practices and sensitive environmental areas along the footprint of the embankments. Alternatively, the alignment could follow the existing levees with siphons/culverts installed at channel crossings in order to minimize impacts to farming activities. This will likely impact the stability and maintenance needs of the levee and could still have environmental impacts. For these reasons, an open canal system was ruled out at this stage.

D.3.2 Buried Gravity Pipeline

A buried gravity flow pipeline was also considered and would require about three 10 foot diameter pipes to deliver 900 cfs, assuming a slope of 0.001 and Manning's n of 0.02. As in the open channel case, this alternative will likely need pumping to lift the water at the beginning of the pipeline to provide necessary head to convey the flow. This alternative was ruled out because the existing ground profile does not lend itself well to provide gravity flow and the number of large pipes required would be cost prohibitive.

D.3.3 Above-Ground Pressure Pipeline

A pressure flow conveyance system would consist of a pumping plant to boost hydraulic head and a pipeline to carry the flow to Clifton Court Forebay.

An above ground pipeline was considered as a possible alternative conveyance system. The above ground pipeline would require minimal excavation and no tunneling at slough crossings. The above ground pipeline would likely be supported by concrete or steel girders and concrete piles every 10 to 15 feet, which could be cost prohibitive. If the pipeline followed the proposed alignment, farming practices would be impacted. This option would also require the pipeline to be raised, or bridges and culverts would need to be constructed, to allow farm machinery to cross the pipeline alignment within the island. Under an alternate alignment the pipeline could follow the existing island levees. This would likely impact the levee maintenance activities carried out by the reclamation districts and would likely require significant environmental mitigation. For these reasons, an above ground pipeline is not recommended.

D.3.4 Buried Pressure Pipeline

Buried pressure flow pipelines are very common. Given the relatively flat existing ground surface profile, pumping will be required to provide the head needed to convey the design flow across the proposed 30,000 ft alignment. A buried pipeline would follow the existing ground profile and it would not significantly impact farming activities on the islands. Higher flow velocities are permitted in a pressure pipeline; therefore, fewer pipes would be required than for the buried gravity pipe system. For these reasons a buried pressure flow pipeline was selected for further evaluation.

D.4 Pipeline Design

D.4.1 Pipe Selection

A number of factors were considered in determining the size and type of pipe selected for this design. These include constructability, capital cost, and operation and maintenance costs.

Both reinforced concrete pipe and steel pipe were considered for the pipeline. The manufacturing cost of reinforced concrete pipe is less than that of steel pipe; however, concrete pipe has some drawbacks, particularly for placement requirements in Delta soils. The concrete pipe weighs about four times as much as steel pipe, which could increase settlement. To avoid settlement, the concrete pipe would need to be supported by piles at every joint (about every 20 feet) whereas steel pipe could be supported as needed since the joints are welded. Reinforced concrete pipe may be cost prohibitive due to the cost of bedding and piles required to avoid settlement, so steel pipe was chosen for this design. Since steel pipe corrodes, it will require a protective coating. Mortar is typically used to coat the interior during fabrication (n=0.015) and coal tar enamel is used around the exterior.

The size of pipe(s) required to carry the 900 cfs design flow was determined based on the velocity criteria and number of pipes assumed. The velocity criteria used to size the pipeline should be sufficient to carry fine sediments in a relatively flat pipeline, as is the case here, so a minimum of 8 ft/sec was used. Two 450 cfs pumps will be used to provide the required head. The pump selection is discussed further in Section 1.5. The total dynamic head of the pipeline system was then determined for comparison. Table D.1 shows the pipe size required and total dynamic head for one and two steel pipes under varying velocity criteria.

Table D.1: Pipe Size Required and Total Dynamic Head

Velocity Criteria (ft/sec)	Number of Pipes	Required Pipe Diameter (ft)	Total Dynamic Head for Each Pump (ft)
8	1	12	63
	2	9	63
10	1	11	86
	2	8	97
12	1	10	125
	2	7	168

Based on the results provided in Table D.1, a velocity of 8 ft/sec was assumed and one 12 ft diameter pipe was selected to the deliver the design discharge of 900 cfs. A higher flow velocity would require a smaller pipe, but it also increases the head loss in the pipe system. Similarly, the required pumping head increases when two pipes are used, especially as pipe velocity increases. The associated construction cost of two pipes along with the increased pumping costs to overcome this additional pumping head may be prohibitive, so two pipes will not be used.

D.4.2 Layout

The proposed pipeline begins at the Bacon Island Santa Fe Cut Integrated Facility, where two additional 450 cfs pumping units will pump water directly from Bacon Island to CCF. The proposed pipeline closely follows the existing ground surface profile. The alignment of the proposed pipeline is shown in Figure D1.

The depth of cover over the pipe depends on the soil properties, groundwater pressures and the strength of the pipe. For this analysis a minimum depth of cover of 6 ft is assumed. Given this minimum depth of cover and a maximum pipe size of 12 feet in diameter (based on transportation limitations), the required depth of excavation will be about 18 feet below the existing ground level, but could be deeper depending on the existing ground profile. The buried pipe will be supported either by stabilized soils and bedding material or by pre-cast piles. The type of support depends on the depth of the peat soil along the proposed alignment and the forces acting on the pipeline.

D.4.3 Channel and Road Crossings

The proposed pipeline crosses three Delta channels (Santa Fe Cut, Woodward Canal, and Old River) and Highway 4 along its alignment. The channels will be crossed by tunneling the pipe beneath the channel bottom. For each channel crossing, the tunnel boring will begin about 500 feet from the existing channel bank. The tunnel will be laid at elevations having dense sandy soil. The dense sandy soil will provide favorable conditions for tunnel boring activities. The tunnel will exit at about 500 feet from the existing slough bank. No structures would be required to cross the existing roads since the pipeline will be buried.

D.4.4 Air Valves

Combination air vacuum release valves are required to release trapped air at high points in the pipeline. These air valves also allow air to enter the pipeline for draining purposes, although this is not necessary in such a flat pipeline. Slope reversals (from positive slope to negative slope) were minimized to reduce the costs associated with air valve installations. Each air valve will be housed in a concrete valve vault to allow easy access and the vault will have a steel plate cover with ventilation. Figure D3 shows a typical air valve installation.

D.4.5 Access Manholes

Access manholes are required to perform routine maintenance and inspections of the pipeline. Manholes will be provided every 500 feet along the alignment and close to low points to make dewatering easier. Each manhole will be a 24-inch Tee and flange housed in a concrete vault to allow easy access and the access vault will have a steel plate cover with ventilation. Figure D4 shows a typical access manhole installation.

D.5 Pump Selection and Pumping Plant Layout

A pumping plant is needed to boost the hydraulic head and convey water through the pipeline. The required dynamic head, as shown in Table D.1, can be provided either by multiple pumps in series or by a single pump. Pumps in series would allow the currently proposed pumps (pumps in place without connection to CCF) to be used for the initial head boost. Under this option, additional booster pump(s) would be needed along the pipeline to provide additional head. Construction of booster pumps along the pipeline could be cost prohibitive due to the cost of the pumping facility, power line extension, access road, and other infrastructure; therefore, the pumps in series option is not recommended at this stage.

The required dynamic head will be provided by a parallel pump system. To minimize submergence requirements, two 450 cfs pumps were chosen rather than one 900 cfs pump. This is important because the reservoir water levels fluctuate widely and the Midbay is not designed to accommodate the submergence requirements of such a large pump. The currently proposed Bacon Island Santa Fe Cut Integrated Facility pumping station will be modified to accommodate the two additional 450 cfs pumping units. These additional pumps will be used solely to pump water through the 30,000 ft pipeline to the CCF intake.

Although the currently proposed pumping plant has enough space to accommodate the two additional pumping units and associated appurtenances, the current piping layout will require slight modifications to accommodate the additional pumps. In particular, the current pumps can simply be shifted toward one end of the pumping plant structure to make room for the additional pumps. The 450 cfs pumps will discharge into the 12 ft diameter pipeline, which will be oriented parallel to the currently proposed 8 ft diameter conduit pipes.

D.6 Outlet Works

The proposed pipeline will discharge into the proposed new Clifton Court Forebay Intake (CCF Intake is currently being designed by DWR's Division of Engineering). The outlet works will consist of an energy dissipater and a short conveyance channel.

A transition will be provided at the pipeline outlet to reduce the velocities of the pumped flow before it is conveyed to CCF. The pipeline exit velocity is fairly low (8 ft/sec) and the outlet will always be submerged, so a submerged hydraulic jump can be used to dissipate the energy. A short trapezoidal conveyance channel, approximately 2,340 feet in length, will connect the pipeline outlet to the downstream end of the new CCF intake. The channel will be lined with rock riprap and will have a mild slope. The connection to the new CCF intake and the conveyance channel layout is shown in Figure D2.

D.7 Cost Estimate

A construction cost estimate was prepared for the direct connection to CCF. The cost estimate includes the cost of the two additional 450 cfs pumping units and associated appurtenances, the 30,000 ft long reinforced concrete pipeline, crossings, air valves, access vaults, outlet works, land and right of way, mobilization, and contingencies.

The costs for the 450 cfs pumping units and associated appurtenances, as well as the costs for the air valves and access vaults were based on the itemized cost estimates for the integrated facility pumping stations, as performed by CH2M Hill. The costs for the reinforced concrete pipeline, crossings, and outlet works were based on the Los Vaqueros Reservoir Expansion Studies, *Project Cost Estimating Methodology Technical Memorandum* (MWH January 2003).

As mentioned earlier, the cost of this direct connection will not be added to the overall In-Delta Storage Project cost. Instead, the cost of this direct connection will be counted as an avoided cost of the proposed fish screens at the new CCF intake. The construction cost estimate for the Clifton Court Forebay connection is provided in Table D.2.

Table D.2: Clifton Court Forebay Construction Cost Estimate

ITEM	QUANTITY	UNIT	$/UNIT	AMOUNT
1. Pumps and Appurtenances (450 cfs)	2	EA	2,989,367	**$ 5,979,000**
2. Reinforced Concrete Pipeline (144")	29,697	LF	1,300	**$ 57,562,000**
3. Crossings				
Santa Fe Cut Crossing (Tunnel 144")	1,603	FT	4,464	$ 7,511,238
Woodward Canal Crossing (Tunnel 144")	1,385	FT	4,464	$ 6,490,835
Highway 4 Crossing (Tunnel 144")	1,132	FT	4,464	$ 5,305,910
Old River Crossing (Tunnel 144")	1,599	FT	4,464	$ 7,492,489
				$ 26,801,000
4. Air Valves (for 144" pipeline)	33	EA	13,450	**$ 444,000**
5. Access Vaults (at 500 ft spacing)	60	EA	12,095	**$ 726,000**
6. Outlet Canal	2,338	LF	847	**$ 2,080,000**
7. Land and Right of Way	35	ACRES	3,000	**$ 105,000**
8. Mobilization [1]	1	LS	4,680,000	**$ 4,680,000**
SUBTOTAL				**$ 98,377,000**
Contingencies (22%) [2]				**$ 21,643,000**
Subtotal with Contingencies				**$ 120,020,000**
Eng Design, Constr Mgmt, Admin and Legal [3]				**$ 24,004,000**
TOTAL COST				**$ 144,024,000**
Annual Operation and Maintenance Cost [4]				**$ 725,000**

1 Mobilization is taken as 5% of construction costs (Items 1-6), excluding land and right of way
2 This cost is 22% of construction cost for contingencies and environmental mitigation
3 This cost is 25% of subtotal with contingencies
4 Annual O&M cost is taken as (1% of pipeline cost + 2.5% of pumps and appurtenances cost)